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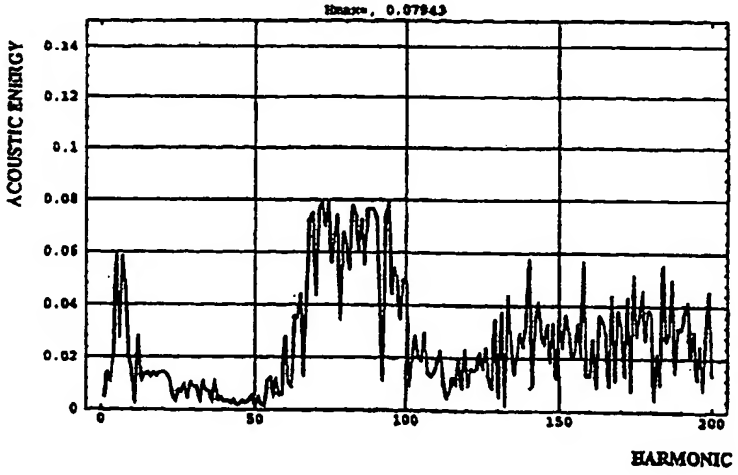

(57) Abstract

The present invention relates to a pneumatic tire having a tread with a plurality of load-supporting elements placed above the circumference of the tire. The tread is characterized by a pitch sequence comprising (a) from 67 to 103 total pitches; (b) only four or five different pitch lengths; (c) a ratio of the longest pitch to the shortest pitch length not to exceed 1.58; (d) a ratio of the longer pitch length to the shorter pitch length of any two pitches which precede or follow each other not to exceed 1.43; (e) there being no instance in the pitch sequence where the shortest pitch length directly precedes or directly follows the longest pitch length; (f) there being a constant increment in pitch length in the four or five different pitch lengths as one progresses from the shortest pitch length to the longest pitch length.

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PNEUMATIC TIRE HAVING IMPROVED PITCH SEQUENCING

Background of the Invention

The present invention relates to a pneumatic tire, more particularly to a tread pattern for pneumatic tire.

As a tire travels upon a surface, there occurs a movement of air, creating an audible sound. For any given tread pattern, a certain amount of acoustic energy is produced. While two different tread patterns may produce the same amount of acoustic energy, the noise produced by each may have dramatically different effects on people. One tire may sound harsh and disagreeable and the other quite acceptable. The difference between the two sounds is in their frequency spectrum and may result in a different subjective audible reaction. The condition where the sound generated is dominated by a single frequency and its harmonics, i.e., a majority of the sound generated being concentrated into very small frequency range of the sound spectrum is undesirable. This situation is psychologically upsetting to a listener, creating an uneasy feeling. Additionally, besides being irritating, total sounds can be perceived at greater distances and require more sound-proofing material than do non-total sounds. If a given concentration of sound energy could be spread out over a wider range of frequency, it would reduce the enology or the undesirability of the sound.

Various methods have been suggested in the past to reduce objectionable noise generated by tires by spreading the energy produced over the frequency range. For example, U.S. Patents 4,327,792 and 4,474,223 disclose a method of spreading noise by load-supporting elements of a tire tread. This is accomplished by designing load-bearing elements in

accordance with a five-step procedure to determine the maximum number of repeating design cycles which may be used, selecting the maximum pitch ratio, determining the appropriate number of harmonic segments into which the tread can be divided, determining the size of each harmonic segment and the number of design cycles for each harmonic segment and lastly arranging the various design cycles in each of the harmonic segments so that the wave length of the predominant modulation frequency of the segment corresponds to the formula length of that segment.

Summary of the Invention

The present invention relates to a tire provided with a tread having a plurality of load-supporting elements placed above the circumference of the tire. The tread has a pitch sequence comprising:

(a) from 67 to 105 total pitches;

(b) only four or five different pitch lengths;

(c) a ratio of the longest pitch length to the shortest pitch length not to exceed 1.58;

(d) a ratio of the longer pitch length to the shorter pitch length of any two pitches which precede or follow each other not to exceed 1.43;

(e) there being no instance in the pitch sequence where the shortest pitch length directly precedes or directly follows the longest pitch length; and

(f) there being a constant increment in pitch length in the four or five different pitch lengths as one progresses from the shortest pitch length to the longest pitch length.

Detailed Description of the Drawings

Figure 1 is a graphical illustration of the Harmonic Analysis of the Impulse function for a tire

tread having 79 pitches made in accordance with the present invention and using the pitch sequence disclosed herein.

Figure 2 is a graphical illustration of the Harmonic Analysis of the Impulse function for a tire tread having 79 pitches made in accordance with U.S. Patent 4,474,223.

Detailed Description of the Invention

As used herein and in the claims, the following terms are intended to mean:

"Pitch" also known as "design cycle" means a section of the tread in the circumferential direction which is repeated around the outer circumference of the tire. Normally, a pitch contains a load-bearing element and an adjacent groove which separates adjoining load-bearing elements in a tire tread. However, the boundaries of a pitch in the circumferential direction may bisect a load-bearing element or adjacent groove, depending on the point on the boundary in the axial direction. Even so, each pitch generally contains the total of at least one load-bearing element and at least one groove, but it may consist of two fractions which total one complete element or groove.

"Pitch ratio" means the ratio of the longest design cycle length to the shortest design cycle length.

"Pitch sequence" means the particular arrangement of different design cycle length segments around the full circumference of the tread.

"Pneumatic tire" means a laminated mechanical device of generally toroidal shape (usually an open torus) having beads, a carcass ply and a tread.

The pneumatic tires of the present invention have improved pitch sequencing. Use of these sequences in

tires result in improved subjective noise properties and are believed to result in reducing uneven tread wear.

The ratio of the longest pitch length to the shortest pitch length should not exceed 1.58. Preferably, the ratio ranges from 1.42 to 1.58.

The ratio of the longer pitch length to the shorter pitch length of any two pitches which precede or follow each other should not exceed 1.43. Therefore, this pitch length ratio ranges from 1.0 to 1.43.

In the pitch sequences used in the present invention, the lowest indivisible integers used for pitch sequences having four pitch lengths are 7, 8, 9 and 10 and for the pitch sequences having five pitch lengths, the pitch ratios are 7, 8, 9, 10 and 11. There is a constant increment in pitch length in the four different pitch lengths and five different pitch lengths as one progresses from the shortest pitch length to the longest pitch length. For example, for the pitch length ratio 7, 8, 9 and 10, there is a constant increment of 1.

There are nine pitch sequences which are preferred embodiments of the present invention. In terms of this pitch ratios, the following sequences are disclosed. The sequences below are interpreted in terms of a closed loop (like a tire) and any pitch can initiate the sequence or terminate the sequence so long as the order of the sequence is maintained.

The first pitch sequence consists of 67 total pitches. The pitch sequence is as follows:

7	9	8	8	9	10	11	9	10	7
10	7	7	7	7	7	9	10	10	8
11	10	11	8	8	8	7	9	8	10

7 7 7 9 8 9 10 10 8 8

7 7 10 11 9 7 7 8 7 7

10 9 8 10 9 11 8 8 8 7

9 10 11 8 8 7 10.

The second preferred pitch sequence has a total of 69 pitches and is as follows:

10 10 9 11 9 7 7 7 8 10

10 8 7 7 7 8 9 9 10 10

7 7 8 9 9 11 8 7 8 7

7 8 8 10 7 7 10 9 9 11

8 9 8 8 9 8 7 8 7 10

10 9 8 8 9 11 9 9 8 8

8 9 7 7 7 9 10 10 9.

The third preferred pitch sequence consists of 71 total pitches and is as follows:

8 8 10 7 8 7 10 8 11 10

10 9 8 7 7 7 8 8 9 11

8 9 7 7 9 10 10 8 7 8

7 7 7 10 8 8 9 7 10 6

8 11 9 9 9 7 8 8 8 7

8 9 8 10 9 10 11 10 10 7

8 9 7 7 7 7 8 9 9 9

11.

The fourth preferred pitch sequence consists of 73 total pitches and is as follows:

9 8 7 8 9 9 9 10 9 8

8 8 8 8 7 7 7 9 8 9

10 9 7 7 8 8 9 9 9 9
10 10 8 8 8 7 7 8 9 9
7 9 9 10 9 10 10 10 10 8
7 7 8 7 7 7 8 10 9 8
9 7 9 10 10 10 8 7 7 7
7 8 10.

The fifth preferred pitch sequence consists of 76 total pitches and is as follows:

7 7 8 8 8 11 9 10 10 9
9 11 8 7 8 8 8 9 11 10
9 8 7 8 8 9 8 7 10 9
11 10 9 8 7 8 8 9 10 8
10 9 7 8 7 7 7 8 10 8
11 9 11 9 10 8 8 8 7 7
8 9 11 8 10 7 8 9 11 11
10 9 8 7 7 7.

The sixth preferred pitch sequence consists of 79 total pitches and is as follows:

8 10 9 11 9 10 8 7 7 8
9 9 10 11 9 8 7 8 8 7
9 8 10 9 11 8 8 7 7 7
7 8 9 9 10 10 10 10 11 8
7 8 9 8 9 7 10 10 7 8
8 8 11 11 10 9 9 8 8 7
7 7 7 8 8 11 9 8 10 11
10 10 9 8 7 7 7 8 9.

The seventh preferred pitch sequence consists of 85 total pitches and is as follows:

8 7 10 9 9 8 8 7 8 7

9 8 10 9 9 8 8 7 9 10

8 11 9 7 8 8 7 8 9 10

10 10 10 9 8 8 8 8 10 7

9 9 9 9 8 10 9 11 8 8

7 7 7 7 8 9 8 9 9 11

10 9 8 9 9 7 7 8 7 8

8 9 10 9 11 10 9 11 10 9

8 7 7 7 7.

The eighth preferred pitch sequence consists of 98 total pitches and is as follows:

11 9 10 9 8 8 9 10 10 8

7 7 7 8 9 9 9 9 9 8

7 7 7 9 11 9 8 8 10 8

8 8 8 10 9 8 7 7 7 8

8 11 10 9 11 9 9 9 7 7

8 10 10 11 8 8 9 8 9 10

9 8 7 7 8 8 7 8 8 8

10 10 9 10 9 8 7 8 9 10

11 10 10 8 7 7 8 9 10 10

9 9 7 8 7 8 8 9.

The ninth preferred pitch sequence consists of 103 total pitches and is as follows:

10 8 11 8 9 10 9 10 9 8

8 7 7 7 7 8 10 9 10 8

9 9 10 9 9 7 7 8 8 7
7 8 9 8 8 9 8 9 10 10
10 10 11 8 7 7 7 7 8 7
9 11 9 7 8 8 8 7 10 8
9 11 9 7 7 7 9 9 8 7
8 9 10 9 8 10 8 7 8 9
8 7 7 8 9 8 9 10 8 7
8 7 8 10 10 9 9 11 8 8
8 7 8.

The tires of the present invention may be for passenger vehicles, multi-purpose vehicles, light truck and medium truck.

According to the present invention, what determines the individual design cycles length on a given tire are the requirements of (a) there being only from 67 to 103 total pitches, (b) only four or five different pitch lengths, (c) the specific pitch sequence, (d) the four or five design cycle length ratios and (e) the known outer circumference of the tire. To determine how long each design cycle would be for a tire of a given outer circumference, one takes the sum of all the integers in the pitch sequence expressed in terms of ratios. For example, for the above 67 pitch sequence, the sum would be 574 ($7 \times 19 + 8 \times 17 + 9 \times 11 + 10 \times 14 + 11 \times 6$). For a tire of the size P195/65R15, the outer circumference would be 2001 mm. If one divides the outer circumference 2001 mm by 574, one gets 3.486. One takes this number 3.486 and multiplies it by 7, 8, 9, 10 and 11 to yield the respective pitch lengths, 24.40, 27.89, 31.37, 34.86 and 38.35.

Example 1

Computer simulation tests have been performed comparing the Harmonic Analysis of the Impulse function of tire treads with pitch sequences arranged according to the present invention versus pitch sequences according to U.S. Patent 4,474,223.

Figure 1 is a graphical illustration of the Harmonic Analysis of the Impulse function using the pitch sequence consisting of 79 individual pitches which are as follows:

8 10 9 11 9 10 8 7 7 8

9 9 10 11 9 8 7 8 8 7

9 8 10 9 11 8 8 7 7 7

7 8 9 9 10 10 10 10 11 8

7 8 9 8 9 7 10 10 7 8

8 8 11 11 10 9 9 8 8 7

7 7 7 8 8 11 9 8 10 11

10 10 9 8 7 7 7 8 9.

Figure 2 is a graphical illustration of the Harmonic analysis of the Impulse function using a pitch sequence consisting of 79 individual pitches in accordance with U.S. Patent 4,474,223 and which are as follows:

7 7 7 7 7 7 7 7 9 9

9 9 9 9 9 9 11 11 11 11

11 11 11 11 9 9 9 7 7 7

7 7 7 9 9 9 9 9 9 11

11 11 11 11 11 9 9 9 7 7

7 7 9 9 9 9 11 11 11 11

9 9 7 7 7 7 7 9 9 9

9 9 11 11 11 11 11 9 9.

In comparing the Figures 1 and 2, it is seen that the Fourier spectrum of the impulse function for the tire tread where the pitch sequence is arranged according to the current invention (Figure 1) has flatter harmonics components than the pitch sequence in Figure 2. The flatter harmonics components translate to reduced tire noise as the tire contacts the road surface. The quality of the calculated Fourier spectrum can be also expressed by a maximum Normalized Amplitude. It is clearly visible from comparison of Figures 1 versus 2 that the maximum Normalized Amplitude calculated from pitch sequence(s) arranged according to the present invention are lower that those arranged in accordance to the U.S. Patent 4,474,223. Accordingly, it has been determined that a tire having pitches arranged according to the current invention has a reduction in tread noise as the tire contacts the road surface. In particular, there is a reduction of the maximum amplitude in 200 harmonic spectrum by more than 20 percent.

WHAT IS CLAIMED IS:

1. A tire provided with a tread having a plurality of load-supporting elements placed about the circumference of said tire, said tread having a pitch sequence characterized by:

(a) from 67 to 103 total pitches;

(b) only four of five different pitch lengths;

(c) a ratio of the longest pitch length to the shortest pitch length not to exceed 1.58;

(d) a ratio of the longer pitch length to the shorter pitch length of any two pitch which precede or follow each other not to exceed 1.43;

(e) there being no instance in the pitch sequence where the shortest pitch length directly precedes or directly follows the longest pitch length; and

(f) there being a constant increment in pitch length in the four or five different pitch lengths as one progresses from the shortest pitch length to the longest pitch length.

2. The tire of claim 1 characterized in that the pitch sequence consists of 67 total pitches and consisting of

7	9	8	8	9	10	11	9	10	7
10	7	7	7	7	7	9	10	10	8
11	10	11	8	8	8	7	9	8	10
7	7	7	9	8	9	10	10	8	8
7	7	10	11	9	7	7	8	7	7
10	9	8	10	9	11	8	8	8	7
9	10	11	8	8	7	10.			

3. The tire of claim 1 characterized in that the pitch sequence consists of 69 total pitches and consisting of

10 10 9 11 9 7 7 7 8 10
10 8 7 7 7 8 9 9 10 10
7 7 8 9 9 11 8 7 8 7
7 8 8 10 7 7 10 9 9 11
8 9 8 8 9 8 7 8 7 10
10 9 8 8 9 11 9 9 8 8
8 9 7 7 7 9 10 10 9.

4. The tire of claim 1 characterized in that the pitch sequence consists of 71 total pitches and consisting of

8 8 10 7 8 7 10 8 11 10
10 9 8 7 7 7 8 8 9 11
8 9 7 7 9 10 10 8 7 8
7 7 7 10 8 8 9 7 10 8
8 11 9 9 9 7 8 8 8 7
8 9 8 10 9 10 11 10 10 7
8 9 7 7 7 7 8 9 9 9
11.

5. The tire of claim 1 characterized in that the pitch sequence consists of 73 total pitches and consisting of

9 8 7 8 9 9 9 10 9 8
8 8 8 8 7 7 7 9 8 9
10 9 7 7 8 8 9 9 9 9
10 10 8 8 8 7 7 8 9 9
7 9 9 10 9 10 10 10 10 8
7 7 8 7 7 7 8 10 9 8
9 7 9 10 10 10 8 7 7 7
7 8 10.

6. The tire of claim 1 characterized in that the pitch sequence consists of 76 total pitches and consisting of

7 7 8 8 8 11 9 10 10 9

9 11 8 7 8 8 8 9 11 10
9 8 7 8 8 9 8 7 10 9
11 10 9 8 7 8 8 9 10 8
10 9 7 8 7 7 7 8 10 8
11 9 11 9 10 8 8 8 7 7
8 9 11 8 10 7 8 9 11 11
10 9 8 7 7 7.

7. The tire of claim 1 characterized in that the pitch sequence consists of 79 total pitches and consisting of

8 10 9 11 9 10 8 7 7 8
9 9 10 11 9 8 7 8 8 7
9 8 10 9 11 8 8 7 7 7
7 8 9 9 10 10 10 10 11 8
7 8 9 8 9 7 10 10 7 8
8 8 11 11 10 9 9 8 8 7
7 7 7 8 8 11 9 8 10 11
10 10 9 8 7 7 7 8 9.

8. The tire of claim 1 characterized in that the pitch sequence consists of 85 total pitches and consisting of

8 7 10 9 9 8 8 7 8 7
9 8 10 9 9 8 8 7 9 10
8 11 9 7 8 8 7 8 9 10
10 10 10 9 8 8 8 8 10 7
9 9 9 9 8 10 9 11 8 8
7 7 7 7 8 9 8 9 9 11
10 9 8 9 9 7 7 8 7 8
8 9 10 9 11 10 9 11 10 9
8 7 7 7 7.

9. The tire of claim 1 characterized in that the pitch sequence consists of 98 total pitches and consisting of

11 9 10 9 8 8 9 10 10 8
7 7 7 8 9 9 9 9 9 8
7 7 7 9 11 9 8 8 10 8
8 8 8 10 9 8 7 7 7 8
8 11 10 9 11 9 9 9 7 7
8 10 10 11 8 8 9 8 9 10
9 8 7 7 8 8 7 8 8 8
10 10 9 10 9 8 7 8 9 10
11 10 10 8 7 7 8 9 10 10
9 9 7 8 7 8 8 9.

10. The tire of claim 1 characterized in that the pitch sequence consists of 103 total pitches and consisting of

10 8 11 8 9 10 9 10 9 8
8 7 7 7 7 8 10 9 10 8
9 9 10 9 9 7 7 8 8 7
7 8 9 8 8 9 8 9 10 10
10 10 11 8 7 7 7 7 8 7
9 11 9 7 8 8 8 7 10 8
9 11 9 7 7 7 9 9 8 7
8 9 10 9 8 10 8 7 8 9
8 7 7 8 9 8 9 10 8 7
8 7 8 10 10 9 9 11 8 8
8 7 8.

11. The tire of claim 1 characterized in that the ratio of the longest pitch to the shortest pitch length ranges from 1.42 to 1.58.

12. The tire of claim 1 characterized in that the tire is for a passenger vehicle.

13. The tire of claim 1 characterized in that the tire is for a multi-purpose vehicle.

14. The tire of claim 1 characterized in that the tire is for a light truck.

15. The tire of claim 1 characterized in that the tire is for a medium truck.

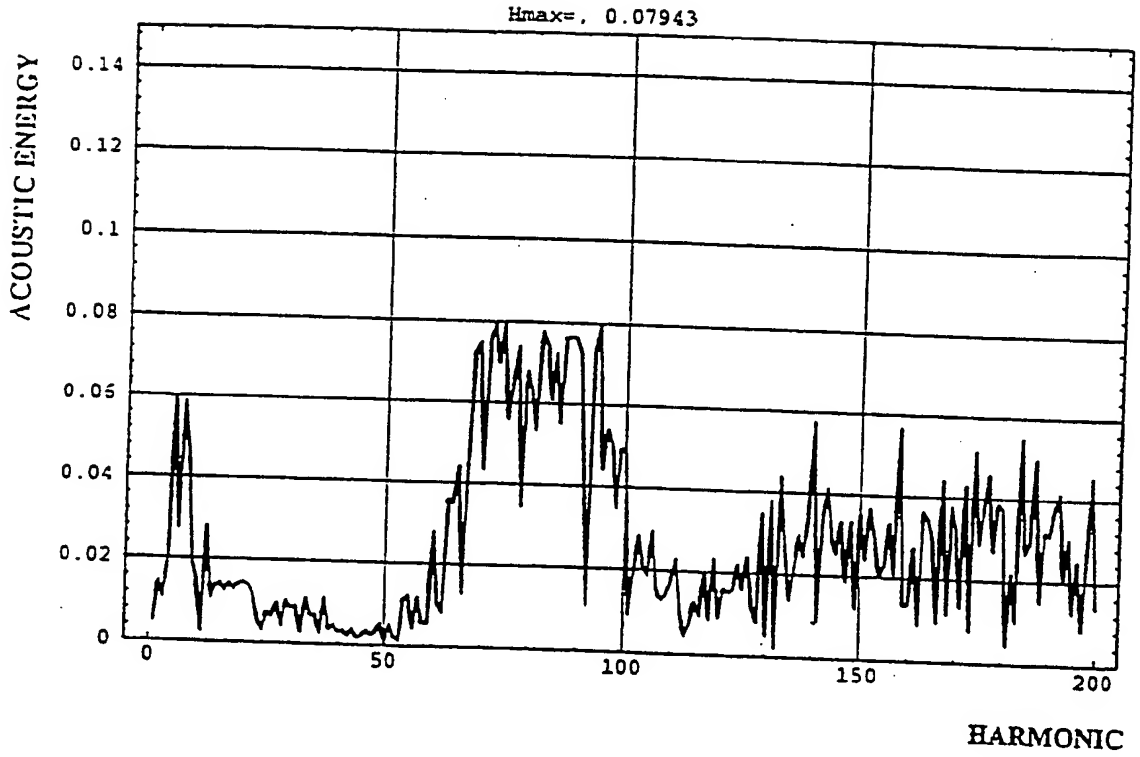
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FIG-1

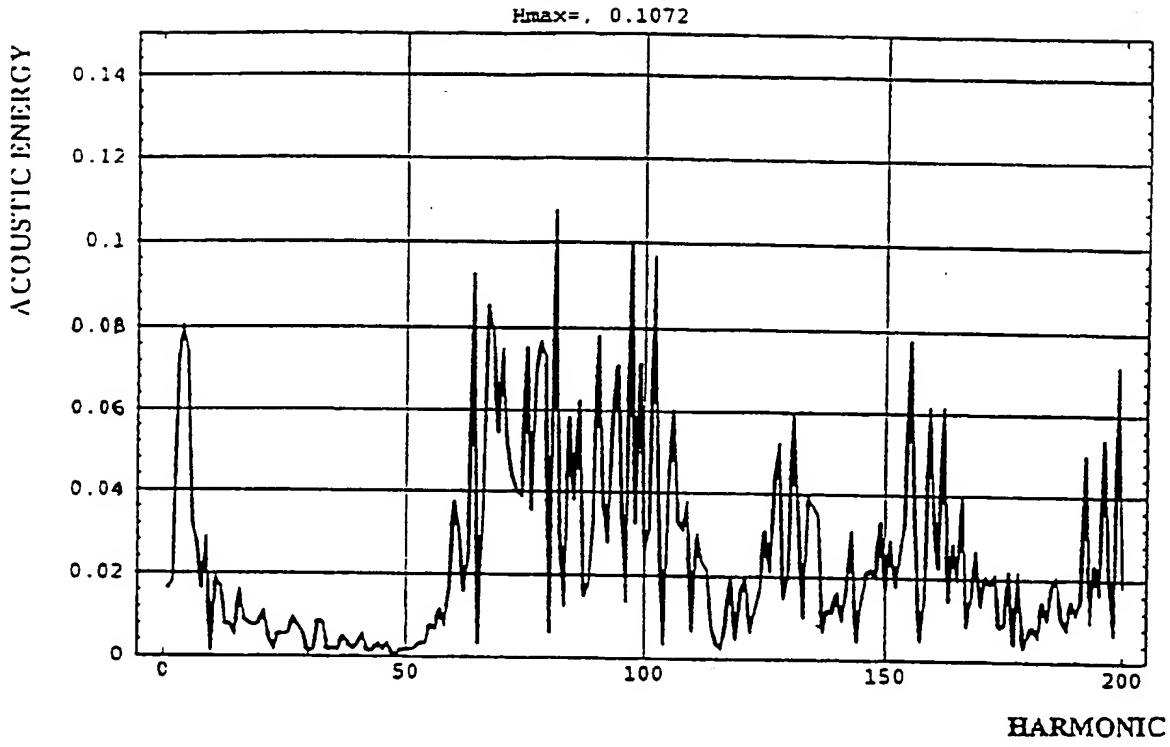
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FIG-2